

#### 3<sup>rd</sup> LHC Detector Alignment Workshop



# Impact of misalignment on track and heavy-flavour reconstruction with the ALICE detector

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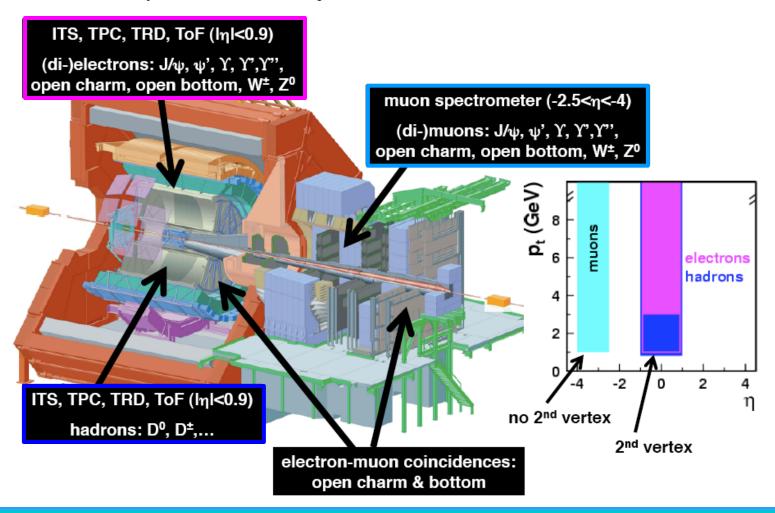
- ALICE heavy flavour program in a nutshell
- Inner Tracking System alignment
  - impact on tracking resolution
  - residual misalignment in view of results from cosmics
  - impact on charm measurement
  - impact on beauty measurement
- Muon spectrometer alignment and quarkonia
- Summary



#### ALICE heavy flavour potential



- Combine electronic (|η|<0.9), muonic (-4<η<-2.5), hadronic (|η|<0.9) channels</li>
- Cover central region (with precise vertexing) and forward region
- Cover also low-p<sub>t</sub> region (low x/X<sub>0</sub> & low field 0.5T, OR forward η)





# Heavy quarks as probes of the Quark-Gluon Plasma medium



- A high-density QCD medium is expected to be formed in high-energy heavy-ion collisions → deconfined Quark-Gluon Plasma
- RHIC experiments have discovered jet quenching -> explore medium properties via its effect on calibrated probes (hard partons)

u,d,s: mass~0 colour triplet gluon: mass=0 colour octet c,b: high mass colour triplet QCD medium

Parton Energy Loss, mainly by medium-induced gluon radiation

QCD: 
$$\Delta E\left( \mathcal{E}_{QGP} \; ; C_R, m \, / \, E, L \right) \\ \Delta E_g > \Delta E_{c \approx q} > \Delta E_b$$

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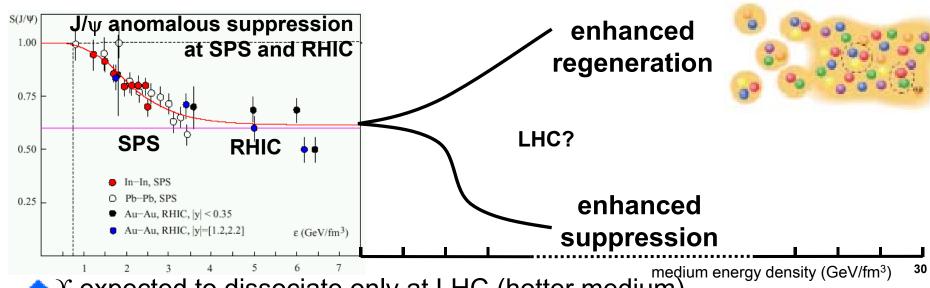
Test mass dependence of QCD energy loss at LHC

- $\rightarrow$  precise measurement of c and b hadrons  $p_t$  distr.
- → alignment of the Inner Tracking System (ITS)

# Quarkonia in Pb-Pb at LHC



J/ψ dissociation (colour screening in a deconfined medium) & regeneration (in-medium coalescence of charm quarks)?



- ◆ Y expected to dissociate only at LHC (hotter medium)
- Less tightly bound Υ' expected to dissociate at same temp as J/ψ

#### Y family separation is crucial

- → di-lepton mass resolution
- $\rightarrow$  alignment of the Muon Spectrometer ( $\mu^+\mu^-$ )
- → alignment of the ITS (e+e-)







	SPD (r = 4 & 7 cm)	SDD (r = 14 & 24 cm)	SSD (r = 39 & 44 cm)
nom. resolutions $\mathbf{x}_{loc} \times \mathbf{z}_{loc} [\mu m^2]$	11 × 100	35 × 25	20 × 830
residual mis. (shifts) x <sub>loc</sub> ×y <sub>loc</sub> × <mark>z<sub>loc</sub> [μm³]</mark>	8 × 10 × 20	20 × 20 × 20	15 × 15 × 100
full mis. "20 μm" (shifts)	20 × 20 × 20	45 × 45 × 45	30 × 30 × 100
full mis. "30 μm" (shifts)  x <sub>loc</sub> ×y <sub>loc</sub> ×z <sub>loc</sub> [μm³]  random misal	30 × 30 × 30	45 × 45 × 45	30 × 30 × 100

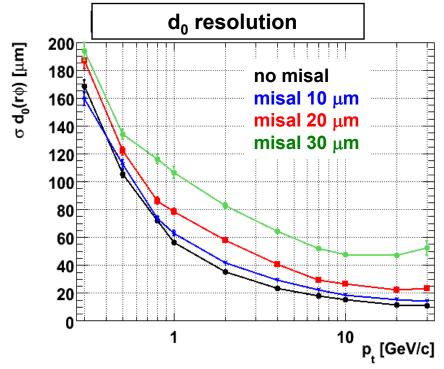
 Target Residual Misalignment: expected misalignment left after realignment, taken ~0.7×resol. → ~20% degradation of the resolution



# Impact of ITS misalignment on ITS+TPC tracking resolutions

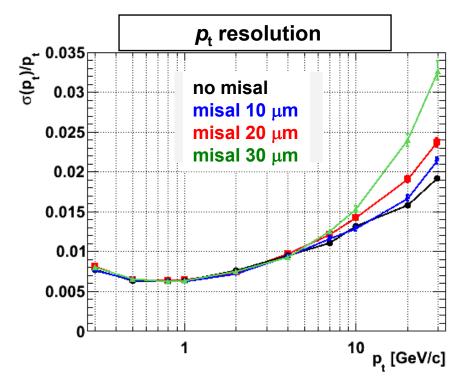


 Effect of misalignment on track impact parameter to the primary vertex (d<sub>0</sub>), p<sub>t</sub>, vertex resolutions studied



effect of misalignment:

- → large worsening
- → factor 2 at high p<sub>t</sub>
- $\rightarrow$  plus 5  $\mu$ m



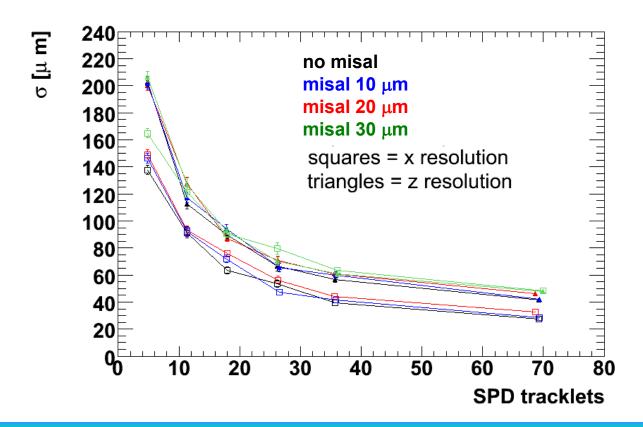
effect of misalignment only above 10 GeV/c



# Impact of ITS misalignment on primary vertex resolution



- Primary vertex reconstructed using tracks with ≥5/6 points in ITS
- Small deterioration (10-20%) with random misalignments <20 μm</li>
- Significant loss of resolution for high multiplicity events with misalignments >30 μm





# Alignment of the Inner Tracking System with cosmics (Summer 2008)

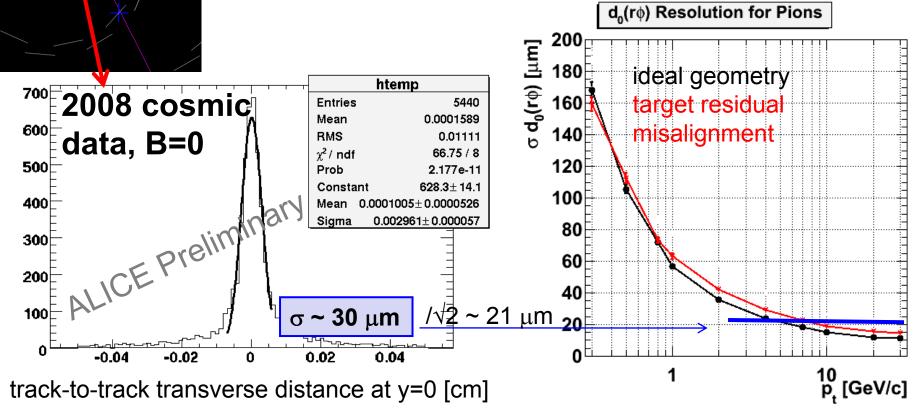






- Millepede alignment SPD+SSD (4 layers)
- Difficult to conclude on resolution ( $p_t$  unknown)

But close to target of residual misalignment



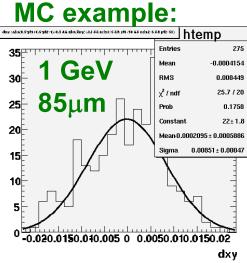


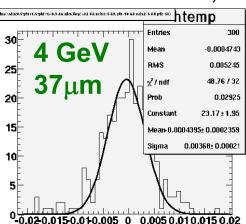
### Alignment of the Inner Tracking System with cosmics (prospects for Summer 2009)

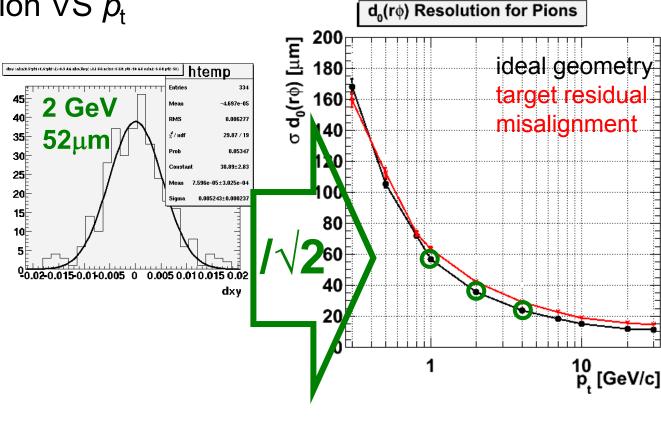


ALICE plans to collect cosmics with B=±0.5T (and B=0)

 $\rightarrow$  Study resolution VS  $p_{t}$ 





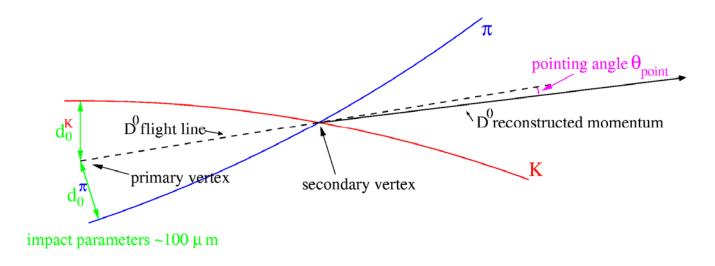




### Impact on charm measurement: $D^0 \rightarrow K\pi$



- Main selection: displaced-vertex topology
  - good pointing of reconstructed D<sup>0</sup> momentum to the primary vertex  $(\cos\theta_{pointing} \rightarrow 1)$
  - pair of opposite-charge tracks with large impact parameters (product of the two impact parameters  $d_0^K x d_0^{\pi} << 0$ )

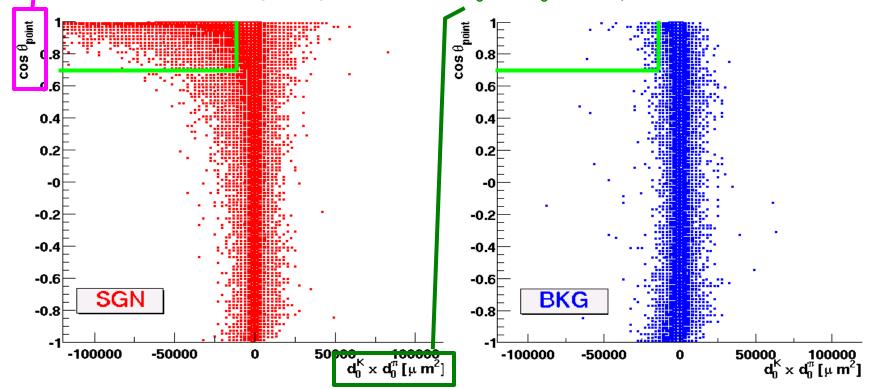




# Impact on charm measurement: $D^0 \rightarrow K\pi$

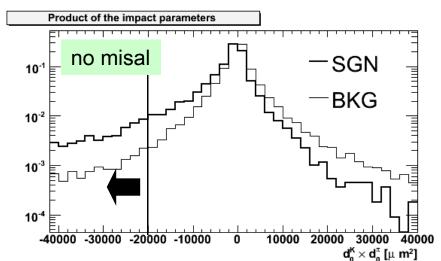


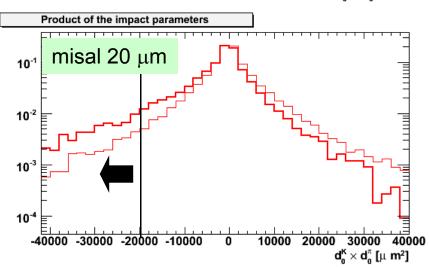
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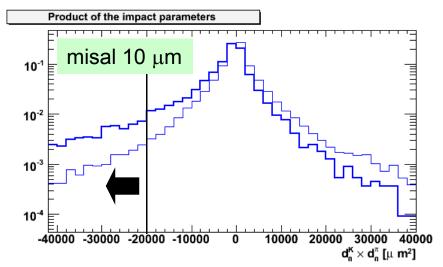


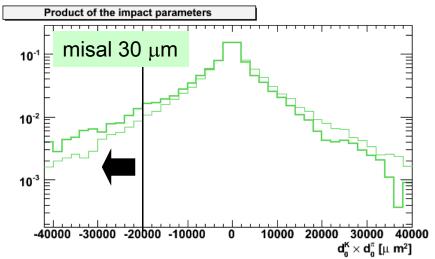


# INFN $D^0 \rightarrow K\pi$ : Product of impact parameters





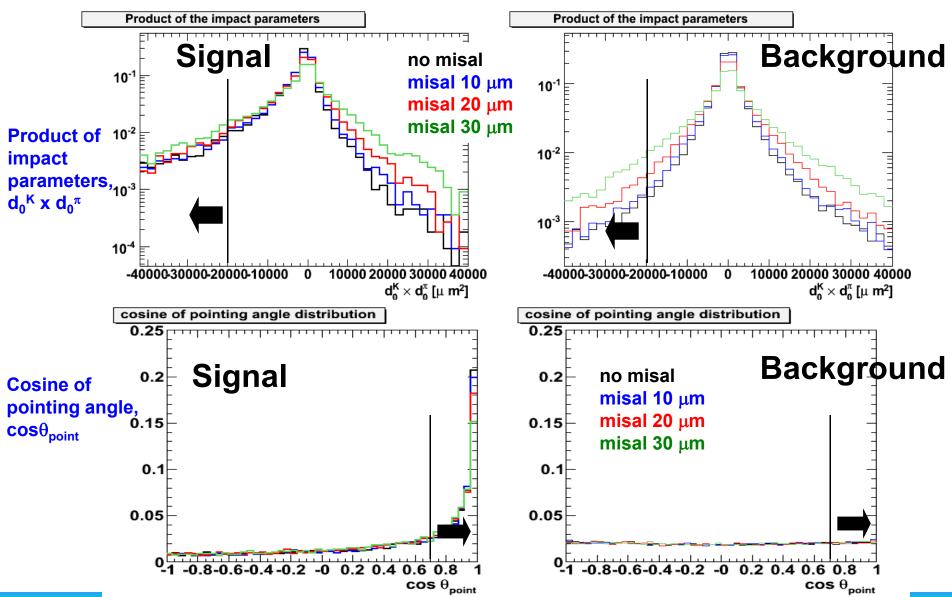






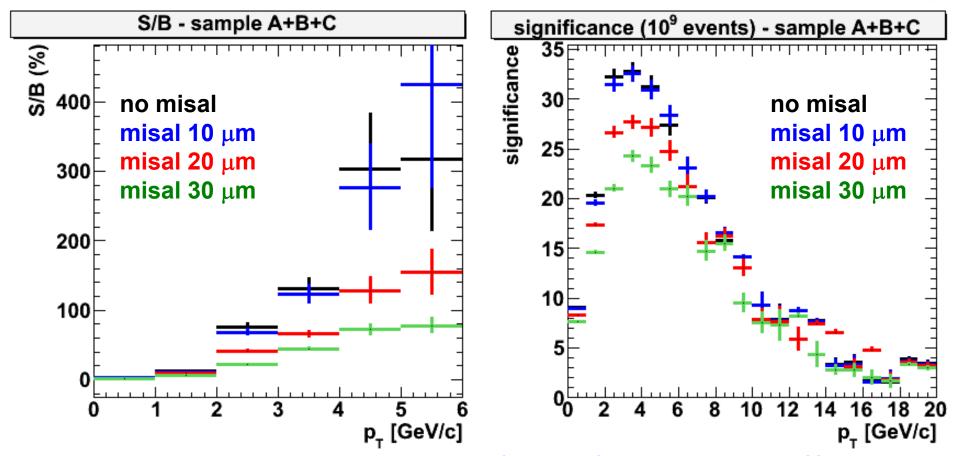
#### $D^0 \rightarrow K\pi$ : selection variables







# $D^0 \rightarrow K\pi$ : Effect on S/B and significance



- Target residual misalignment (10 μm): negligible effect
- 30 μm misalignment: 30% worsening of statistical errors
  - warning: this is much better than "no-realignment"

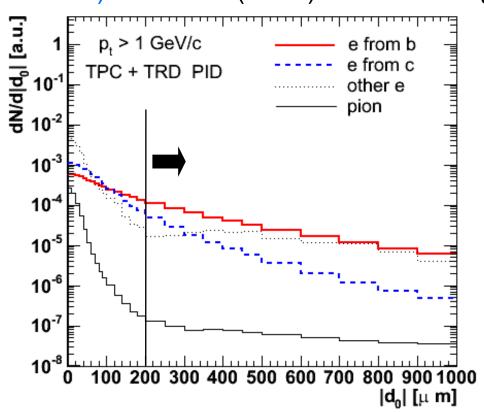


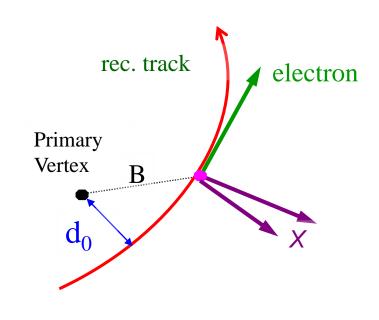
# Impact on beauty measurement: displaced single electrons method



#### Mesurement strategy:

- 1) Electron PID (TPC+TRD): reject most of the hadrons
- 2)  $d_0$  cut ~200  $\mu$ m: reduce charm and bkg electrons (Dalitz,  $\gamma$  conv.)
- 3) Subtract (small) residual background (ALICE data + MC)



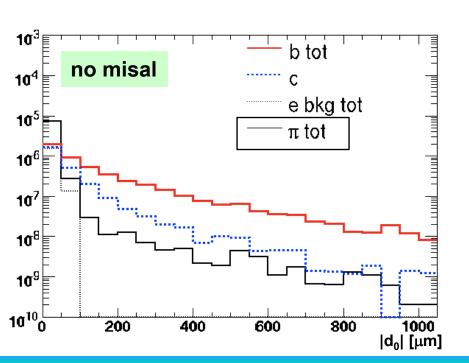


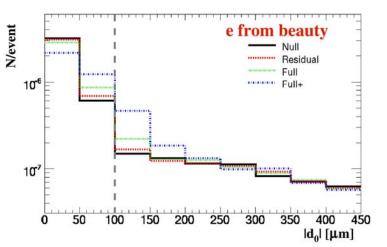


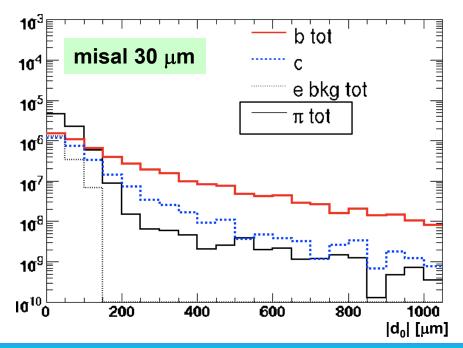
# B→e+X: impact parameters (5<pt<7 GeV/c)



- Impact parameter distributions become broader with misalignment
  - negligible for target residual misal
- Shape charm and background approaches that of beauty for misaligment > 30 μm



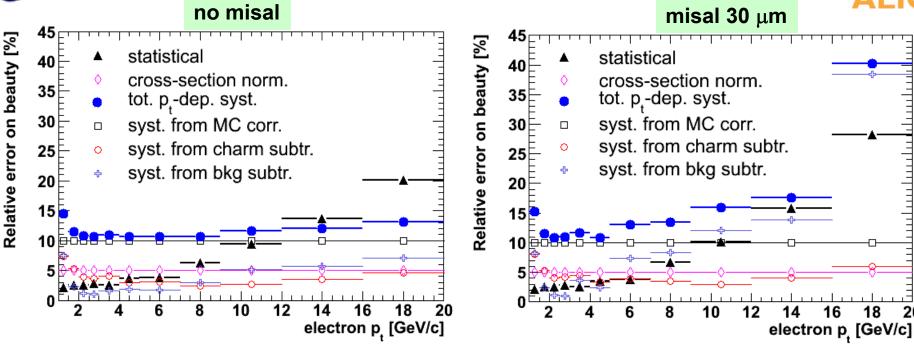






#### B -> e+X: cross section errors vs p,





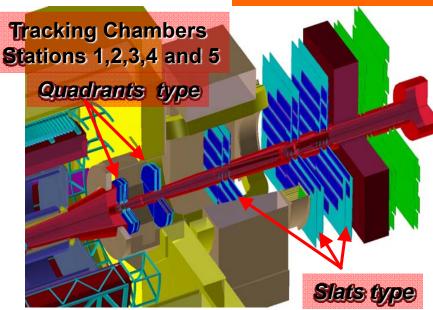
- For a misalignment of 30  $\mu$ m in SPD, the performance at high  $p_{\rm t}$  (>10 GeV/c) deteriorates significantly
  - statistical error on b signal
  - systematic error from misidentified  $\pi$  subtraction  $\Box$
- For the target residual misalignment (<10 μm in SPD),</li>
   there is no deterioration of the performance

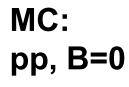


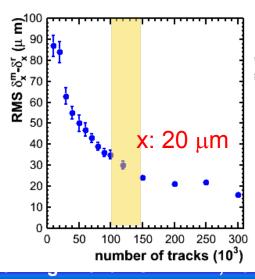
### Muon spectrometer alignment

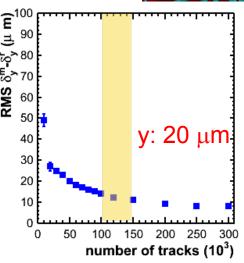


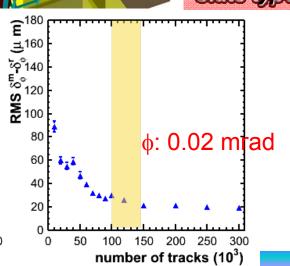
- Expected mounting precision (survey+photogrammetry):
  - chambers x,y,z ~ 1 mm
  - detection elements x,y,z ~ 500 μm
- Alignment requirements: x, y < 50 μm</li>
- Geometrical Monitoring System:
  - chambers x,y,z ~ 20 μm
- Track-based alignment with Millepede:







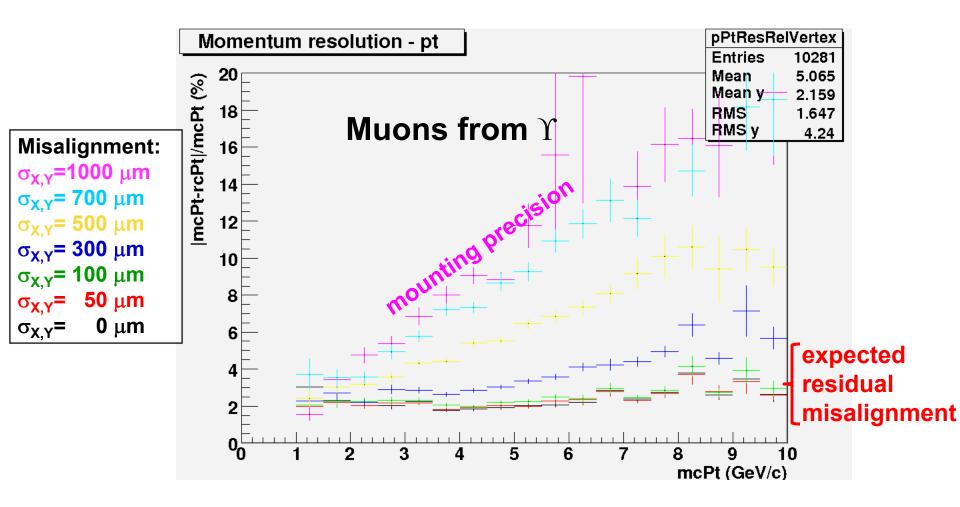






## INFN Muon spectrometer alignment: p₁ resolution

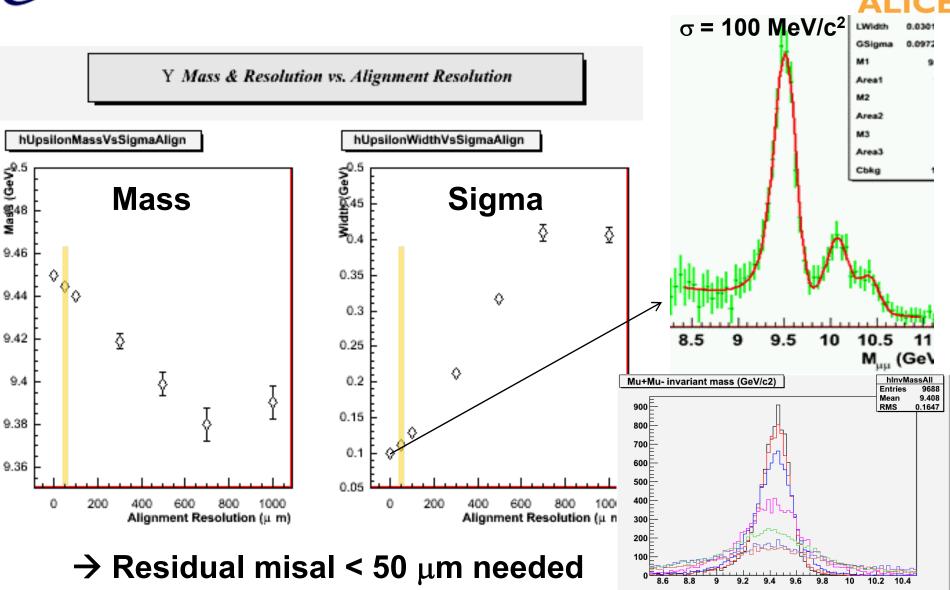






#### Muon spectrometer alignment: Y







#### Muon spectrometer alignment: J/ψ



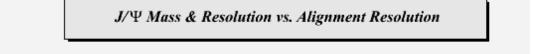
hlnvMassAll

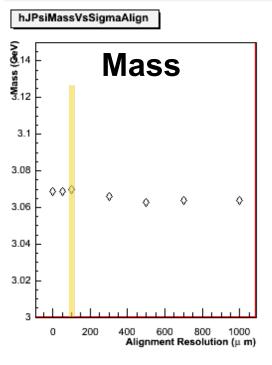
6593 3.052

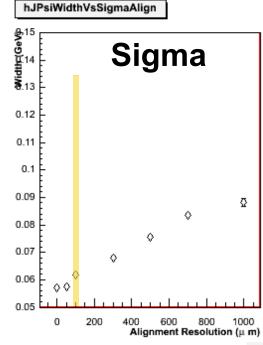
0.09256

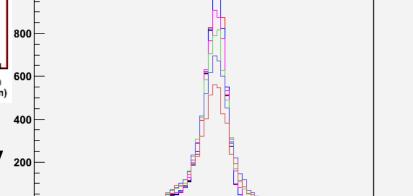
**Entries** 

Mean









3.2

3.6

3.8

- → Residual misal ~ 100 µm seems satisfactory
- $\rightarrow$  Residual misal  $\sim$  50  $\mu$ m perfect

Iu+Mu- invariant mass (GeV/c2)

000



# Summary



- Heavy flavour measurements have a central role in ALICE Physics program
  - heavy quark energy loss in high-density QCD matter
  - quarkonia as a termometer of the QGP
- Importance of detector alignment
- Inner Tracking System:
  - promising results from cosmics, target residual misal ~10 μm seems realistic
  - $\rightarrow$  < 5 µm effect on track position resolution (d<sub>0</sub>)
  - $\rightarrow$  negligible effect for benchmark channels D<sup>0</sup> $\rightarrow$ K $\pi$  and B $\rightarrow$ e+X
  - \* 30  $\mu$ m misalignment would deteriorate significantly the performance at high  $p_t$  (important for energy loss study)
- Forward muon spectrometer:
  - <50 μm residual misalignment needed to prevent worsening of mass resolution and to allow good separation of Υ family





### **EXTRA SLIDES**



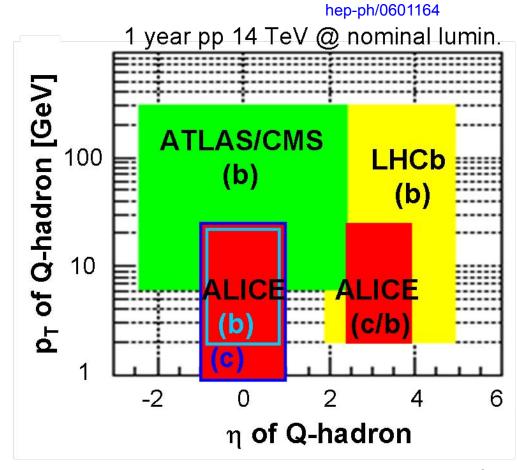
# ALICE heavy-flavour potential



CERN/LHCC 2005-014

 ALICE combines electronic (|η|<0.9), muonic (-4<η<-2.5), hadronic (|η|<0.9) channels

- ALICE covers central and forward regions
- Precise vertexing in the central region to identify
   D (cτ ~ 100-300 μm) and
   B (cτ ~ 500 μm) decays
- ALICE covers the low-p<sub>t</sub> region (B=0.5T)

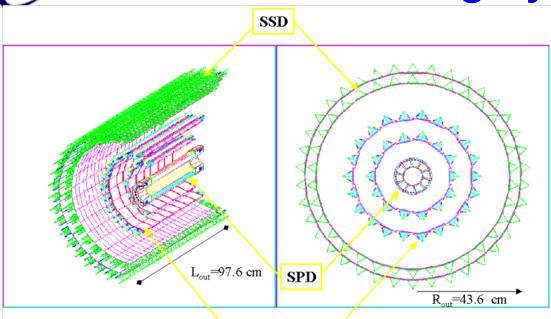


A.Dainese (ALICE) M.Smizanska (ATLAS) C.Weiser (CMS) U.Uwer (LHCb)



### Inner Tracking System (ITS)





Silicon Pixel Detector (SPD):

- ~10M channels
- 240 alignable vol. (60 ladders)

Silicon Drift Detector (SDD):

- ~133k channels
- 260 alignable vol. (36 ladders)

Silicon Strip Detector (SSD):

- ~2.6M channels
- 1698 alignable vol. (72 ladders)





ITS total:
2198 alignable
sensitive
volumes
→ 13188 d.o.f.